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Implementing Zonal Aquaculture Innovation Platforms in Uganda: Key Lessons Learned

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Abstract: Uganda’s aquaculture sub-sector is rapidly developing, contributing up to 22% of all fish produced in the country. However, this sub-sector still faces challenges related to limited access to extension services, production inputs, post-harvest handling facilities, disease incidences, value-addition skills, and weak market linkages. Although there have been isolated interventions at different aquaculture value-chain nodes, the registered challenges continue to recur. To address prioritized issues in Uganda’s aquaculture sub-sector, nine zonal aquaculture innovation platforms were established based on the country’s nine agro-ecological zones. These platforms brought together different stakeholders to identify solutions to common problems in each aquaculture value-chain node. Each innovation platform consisted of fish farmers, hatchery operators, traders, extension workers, researchers, input dealers, local leaders, and financial institutions. During a series of zonal workshops, participants identified constraints on the aquaculture sub-sector in their respective zones. From the findings, there are technical knowledge gaps across the entire aquaculture value chain, mainly affecting hatchery operators, input suppliers, and farmers. Therefore, there is need for coordinated interventions to enhance access to production technologies, innovations, knowledge, and skill transfer to promote gender-centered aquaculture development.

Keywords: agro-ecological zones; aquaculture; innovation systems; innovation platforms

1. Introduction

Aquaculture is one of the fastest-growing food production systems, contributing to global food security and nutrition [1]. However, the sub-sector requires scaling up transformative changes in policy, management, innovation, and investment to achieve sustainable, inclusive, and equitable growth. Innovation and technological changes can play important roles in poverty reduction [2,3]. This is most applicable to the aquaculture sub-sector, where its contribution to global production of aquatic food reached a record 49.2% in 2020 [1]. Thus, for the aquaculture sub-sector to maintain its role as a globally important sub-sector, continual innovation in farming systems is necessary to address key issues such as feed quality, seed quality, and opening up new markets [4,5]. Innovation in the aquaculture sub-sector is considered important for alleviating existing production risks and transformation towards sustainable intensive production.

Innovation platforms (IPs) have become increasingly popular as a framework for organizing multi-stakeholder interactions and exploring ideas, people, and resources to address challenges and opportunities embedded in complex settings [5]. Specifically, an IP has been defined as “a physical, virtual, or physical-virtual network of stake-holders who are set up around a commodity or system of mutual interest to foster collaboration, partnership, and mutual focus to generate innovations to guide a commodity or system” [6,7]. IPs are portrayed as temporary structures, involving selected key actors relevant to an issue or purpose, whose establishment is facilitated but may start to act independently [8]. Although IPs have only recently joined the toolkit of agricultural research for development programs in Uganda, they are currently widely used as a core part of strengthening agricultural productivity, smallholder farmer livelihoods, and agricultural innovation systems [9].

IPs have been used in the agricultural sector to facilitate interactive learning, thereby enhancing the ability to respond to collective challenges and identified needs [10,11]. In Uganda, success stories related to the establishment of IPs in different agricultural sectors have been reported [12,13]. For example, Ahimbisibwe et al. [13] documented the establishment of the Cassava Innovation Platform (CIP), which focused on strengthening the distribution and dissemination of clean planting materials among cassava farmers for increased household income. In aquaculture, IPs play an important role in solving production and marketing challenges, contributing to the transformation of the sector, as evidenced in Bangladesh, Vietnam, and Thailand [5]. Despite the importance of IPs in enhancing sustainable agriculture in many parts of the world [14], their application in Uganda’s aquaculture sub-sector is still lacking. As such, the aquaculture value chain is still characterized by uncoordinated small-scale, medium- to large-scale commercial fish farmers, processors, input dealers, and middlemen/merchants/traders [15] that are disjointed. These stakeholders operate in a complex and uncertain environment, which requires continuous improvement and innovation. Consequently, effective uptake pathways through IPs are required to improve aquaculture growth over linear and less inclusive traditional research and extension approaches that are currently used in Uganda [16].

The adoption of IPs in aquaculture has the potential to enhance the sub-sector’s impact on poverty reduction, food security, and economic development. Therefore, through the project titled “Strengthening Agricultural Knowledge and Innovation Ecosystem for Inclusive Rural Transformation and Livelihoods in Eastern Africa (AIRTEA)”, the National Agricultural Research Organization (NARO), together with partners created and implemented zonal aquaculture platforms in Uganda to coordinate value-chain actors to foster a collaborative system aimed at enhancing aquaculture productivity, profitability, and sustainability for inclusive growth and development. By bringing together farmers, aquaculture input dealers, fish processors, traders, researchers, financial institutions, and extension workers, IPs will provide a platform for collaboration and coordinated advancement in both technological development and social and institutional change.

2. Materials and Methods

2.1. Formation of Zonal Aquaculture IPs

The formation of zonal aquaculture IPs went through a stage-wise process, which included the identification and mobilization of actors, the formation of a visioning strategy, and the formation of steering committees (Figure 1). A framework for routine IP meetings was established to enhance participation, commitment, and ownership. In addition, capacity building, facilitation, management, and resource mobilization were considered important during IP formation. Steering committee members were identified as one of the initial activities of the IP formation process. The roles of the selected committee members included strategic action planning, technical management, and process management. Other roles included fundraising, networking and information sharing, lobbying and advocacy, and monitoring and evaluation at the zonal level. The criteria for the identification of IP leaders were based on their experience in aquaculture development work and local leadership. Relatedly, operational guidelines for the zonal innovation platforms were developed by the stakeholders under the guidance of innovation zonal coordinators. To enhance IP sustainability, business models were developed, and membership subscription systems were established to create a sense of ownership and belonging.

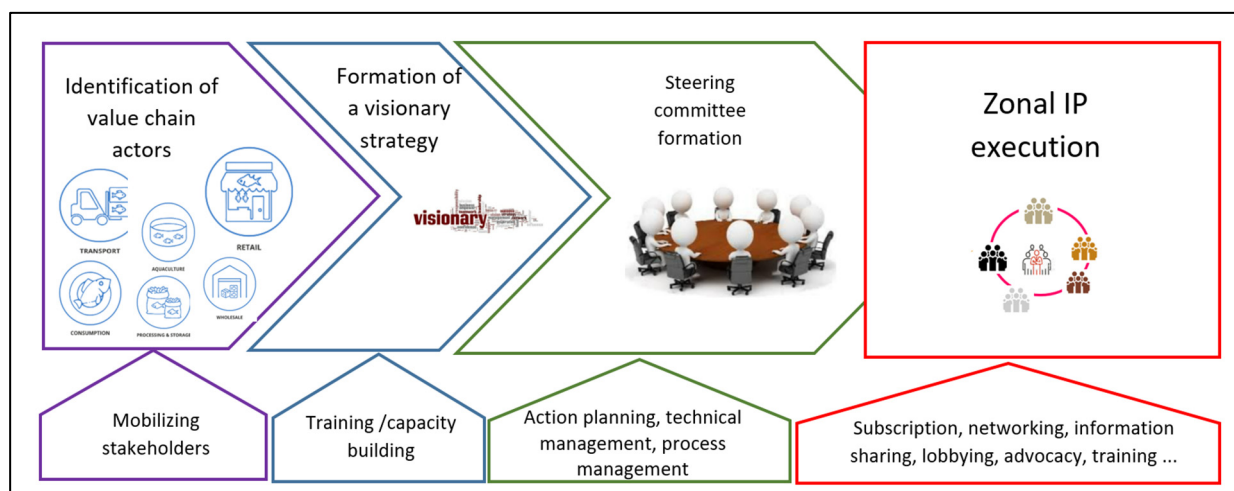


Figure 1. The innovation platform formation process.

2.2. Multi-Stakeholder Workshops

A participatory approach through workshops was adopted to facilitate different groups of stakeholders to identify, categorize, and analyze constraints and propose solutions and strategies in aquaculture. The multi-stakeholder groups were guided through a series of participatory exercises to identify, in each group, the top five constraints through ranking to achieve sustainable aquaculture production in their zones. Nine workshops were held in nine agro-ecological zones of Uganda (Figure 2) from September 2022 to January 2023. For each zone, a workshop was designed to take a day. The nine zonal IPs established through the AIRTEA project provided a natural experiment for understanding the challenges facing the aquaculture value chain in different zones.

2.3. Data Collection

A Rapid Appraisal of Agricultural Innovation System (RAAIS) stakeholder workshop methodology was used to collect information, as described by [17]. We adapted the RAAIS method previously used in agriculture to aquaculture (i.e., the Rapid Appraisal of Aquaculture Innovation System). The nine workshops were held in the language that all participants spoke and understood, and each workshop was facilitated by a zonal coordinator who was familiar with the cultural norms and understood the realities of the different stakeholder groups. The workshop methodology consisted of three sessions subdivided

into three categories, with each focusing on (1) identifying constraints, (2) categorizing constraints, and (3) exploring entry points for innovation.

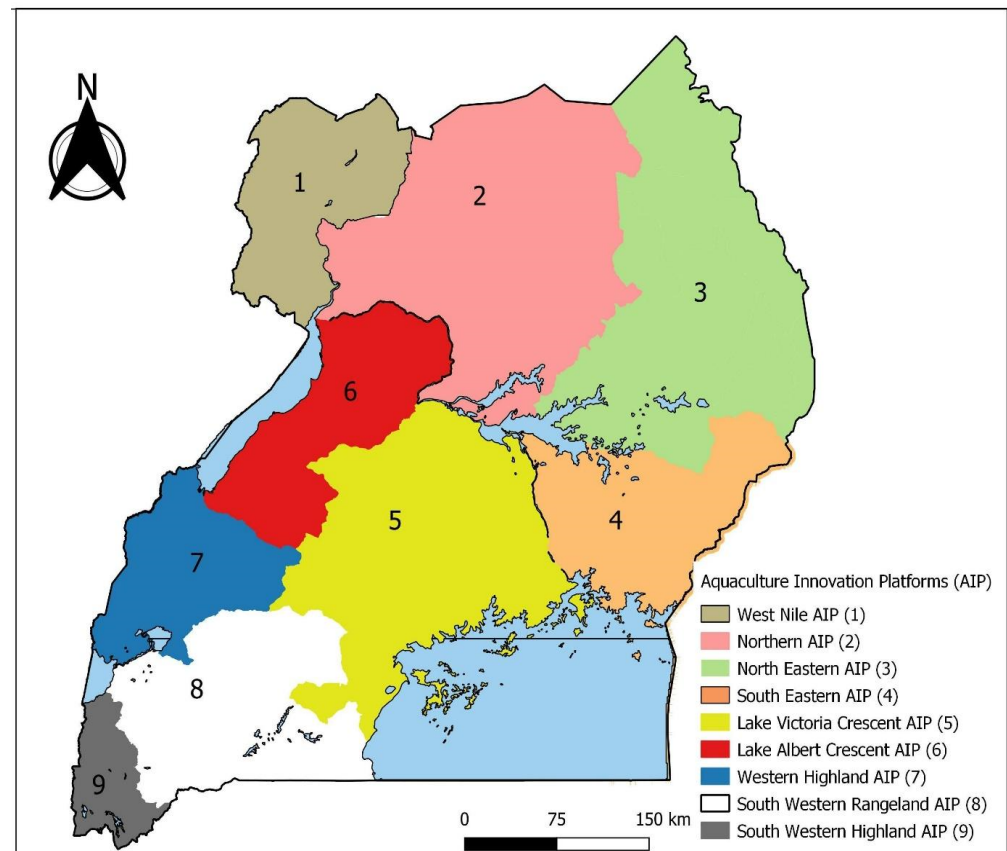


Figure 2. A map of Uganda showing the locations of aquaculture innovation platforms established through workshops held in the different agro-ecological zones from September 2022 to January 2023. AIP = aquaculture innovation platform.

3. Results and Discussion

Innovation platforms are viewed as effective approaches to enhancing agricultural productivity. Globally, they create an enabling environment for scaling up new technologies, practices, and ideas among different stakeholders [12,18]. Despite the importance of innovation platforms in agricultural research, information regarding their applications in the aquaculture sub-sector in Uganda is lacking. With a rising interest in IPs to support agriculture transformation in Uganda, such knowledge is essential for improving the design of aquaculture innovation systems. Therefore, we present key findings and discussion from the formation of aquaculture innovation platforms across Uganda's agro-ecological zones.

3.1. Gender and Composition of Participants

A total of 438 participants were part of the IP formation process (Figure 3). During IP formation, the following parameters were considered: inclusion and representation; the identification of constraints and opportunities; inventory of knowledge, skills, and interests; organizational structure and governance; and resource availability. The analysis of the results obtained from this study revealed that the South Eastern Aquaculture Innovation Platform had the highest number of women participants, followed by the Lake Victoria Crescent Aquaculture Innovation Platform. The Western Highland Aquaculture Innovation Platform had the least representation of women (Figure 3). The differences in female participation may be attributed to a number of factors, such as access to information and basic inputs, as well as improvements in the provision of extension services and government support. Specifically, women from the South Eastern and Lake Victoria Crescent agro-

ecological zones have received support from a number of international development agencies, such as the Food and Agriculture Organization (FAO), United States Agency for International Development (USAID), and the United Nations Industrial Development Organization (UNIDO). In addition, women from these two zones have greatly benefited from several research innovations, particularly the improved fish smoking kilns. Through these efforts, fish farming activities have been promoted in the South Eastern and Lake Victoria Crescent agro-ecological zones as compared to others. All these could explain their positive attitude and subsequent response to the innovation platform idea. However, the results generally showed the presence of more male involvement in IP-related activities than women across the different agro-ecological zones. This observation is similar to that presented by Kruijssen et al. [18], who noted that although aquaculture generates significant employment opportunities at multiple scales, men and women are not necessarily able to participate in aquaculture value chains in the same way, and benefits may not be evenly distributed between them.

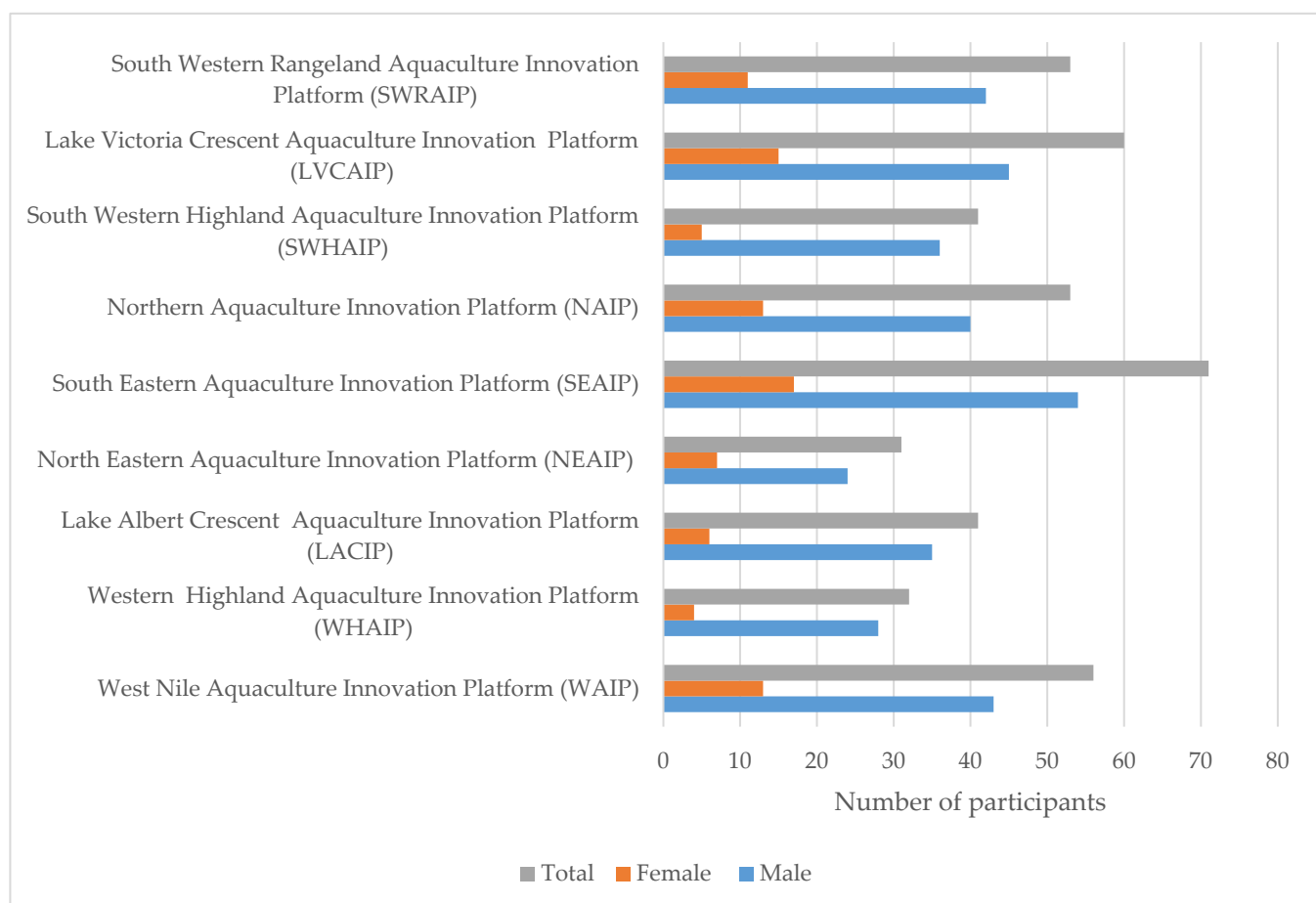


Figure 3. The number of participants in each zonal aquaculture innovation platform (AIP) during workshops held across Uganda from September 2022 to January 2023.

3.2. Composition and Diversity of Stakeholders in Zonal Aquaculture Innovation Platforms

The success of the IPs was analyzed in terms of the diversity of actors, attendance at meetings, and their ability to mobilize and organize their zonal constituent members to engage in IP activities. The actors invited to the meetings included fish farmers, the private sector, financial institutions, researchers, training institutions, non-government organizations (NGOs), and civil society organizations (CSOs) (Table 1). The identification of actors was largely influenced by the nature, mandate, knowledge, and experience of various stakeholders.

Table 1. Stakeholder groups and their diversity during zonal aquaculture IP formation.

Stakeholder Groups	Diversity within Stakeholder Groups
Fish farmers	Smallholder hatchery operators and grow-out farmers
Private sector	Input and service providers (seed and aqua input dealers and private extension agents), aquaculture entrepreneurs (fish processors, traders, retailers, and transporters), and financial institutions
Government agencies	Politicians, policymakers, and fishery extension officers
Research and training institutions	National agricultural research institutes, agricultural training, and institutes and universities
NGO and CSOs	Agricultural networks and associations, cooperatives, and development organizations

3.3. Focus Areas of Zonal Aquaculture Innovation Platforms

During IP establishment, different actors from each of the zonal aquaculture IPs identified focus areas to be addressed within a period of two years. These aims are listed in Table 2. Almost all of the nine IPs highlighted uncoordinated value chain actions, which negatively affect the productivity and profitability of aquaculture. Different social media platforms were established to ensure information flow between actors from different zones.

Table 2. Focus areas were identified by participants at the different zonal aquaculture IPs at the time of establishment.

IP Name	Period of Establishment	Purpose of Establishment
West Nile Aquaculture Innovation Platform	September 2022	Enhance fish production and marketing in West Nile
Western Highland Aquaculture Innovation Platform	December 2022	Improve relationships between fish farmers and other actors within the aquaculture value chain
Lake Albert Crescent Aquaculture Innovation Platform	December 2022	Strengthen relationships and linkages among actors
North Eastern Aquaculture Innovation platform	December 2022	Enhance supply and demand for quality seed
South Eastern Aquaculture Innovation Platform	December 2022	Link farmers to markets, quality fish feed, and seed supplies
Northern Aquaculture Innovation Platform	January 2023	Enhance coordination among farmers
South Western Highland Aquaculture Innovation Platform	January 2023	Sustainably increase incomes of actors through better integration of aquaculture production systems
Lake Victoria Crescent Aquaculture Innovation Platform	January 2023	Improve access to aquaculture production inputs
South Western Rangeland Aquaculture Innovation Platform	January 2023	Link farmers to markets, quality fish feed, and seed supplies

3.4. Constraints and Opportunities Identified

Designing and implementing a sustainable development intervention requires the involvement of diverse stakeholders (farmers, non-government organizations (NGOs), the private sector, and government agencies) in a collaborative participatory process [19]. Effective interaction is needed between farmers, businesses, service providers, researchers, policymakers, development organizations, and other stakeholders for innovation to occur. Similarly, all of the nine zonal platforms were able to bring together multiple public and private actors to engage in an attempt to collectively address key problems in the aquaculture value chain. Based on the discussions that were carried out in the different IPs, this study revealed that the main challenges affecting the aquaculture subsector relate to technical, biophysical, market, and socio-cultural aspects.

During the zonal workshops, participants identified several aspects that limit the growth of the aquaculture sub-sector in their respective zones. Stakeholders identified several challenges at the various nodes of the aquaculture value chain, suggested possible

interventions and solutions, highlighted how the formation of the innovation platforms would support the development of the aquaculture value chain, and also suggested strategies for sustaining the functionality and success of the innovation platforms. Most of the identified issues reflect rather complex problems that have technical, organizational, and institutional connotations, as discussed below.

3.4.1. Fish Farmers

Fish farmers identified high cost of feed and poor feed quality as major constraints to the viability of aquaculture across all zones in Uganda (Table 3). This observation is similar to findings from other African countries that noted the availability of quality and affordable fish feed as major bottlenecks and estimated that feed accounts for 50 to 85% of production costs [15,20,21]. The high feed cost situation is complicated by the lack of adequate local capacity to produce sufficient feed to satisfy the demand. While a few small-scale to medium-scale farms can produce their fish feeds, sourcing feed ingredients makes it challenging to produce sufficient quantity and quality. This is further complicated by the inadequate capacity to supply feed and insufficient regulation to guarantee feed quality standards [15,22]. Although commercial farms can import quality fish feed in bulk, costs remain high.

The poor quality of domestically produced feed is partly attributed to the adulteration of fishmeal, a major protein source, with shells and sand to increase weight. This practice is rampant in the local markets and greatly affects fish feed quality and increases production costs for small-scale aquaculture producers [23]. Addressing concerns in Uganda's fish feed raw material value chain would greatly lower costs, increase quality, and have spill-over effects on other livestock value chains such as poultry. Farmers also observed that the establishment of an association between fish feed importers or manufacturers and the identification of inexpensive alternatives raw materials could be a suitable strategy for combating high feed production costs.

Across all zones, farmers expressed concerns about limited access to quality Nile tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*) seed (Table 3). They noted that some hatcheries did not disclose the true type of seed they produced, which affected production targets and productivity. Farmers reported obtaining fingerlings labeled as all-male Nile tilapia, but these were later reproduced in grow-out fish ponds. The challenge of poor aquaculture seed is not limited to Uganda; it has been reported in Nigeria with *Clarias gariepinus*, and *Oreochromis niloticus* in Kenya [20,24] and sub-Saharan Africa as a whole [25]. Uganda's seed quality challenge is further complicated by low productivity, a limited number of functional hatcheries, inefficient production technologies, and lack of standardized hatchery protocols [26].

In line with previous findings in the Rwenzori region, Uganda [27], and South Africa [28], farmers across zones noted a lack of aquaculture knowledge and skills. Aquaculture skills remain deficient amongst fish farmers in Uganda, which is largely attributed to limited expertise within the present extension structure in the aquaculture sub-sector. Since the early 2000s, efforts have been made to train aquaculture professionals (initially at Makerere University and later on at Busitema and Nkumba Universities) in Uganda. Currently, a good number of scientists have acquired advanced training and practical knowledge in aquaculture science and technology; however, small-scale farmers are hesitant to pay for aquaculture technical services, which demoralizes extension workers. On the other hand, in private commercial farms where professional services are remunerated, this technical labor force provides the necessary technical and management services. As a result, Uganda has recently experienced increased investment in cage aquaculture, particularly on Lake Victoria, which is mainly privately-led, a situation that has resulted in a rise in national aquaculture production volumes [22]. Therefore, the practice of the formation of associations or platforms, which this project has contributed to, is one of the strategies that could be adopted to facilitate improved access to quality aquaculture extension services by small-scale farmers since IPs provide for collective advocacy for demanded services.

Table 3. List of key constraints as identified by fish farmers, hatchery operators, fish traders, processors, and transporters during zonal aquaculture innovation IP workshops in the various agro-ecological zones around Uganda.

Category	Constraints Identified	Ranking of Challenges According to Innovation Platforms								
		WAIP	WHAIP	LACIP	NEAIP	SEAIP	NAIP	SWHAIP	LVCAIP	SWRAIP
Fish farmers	Expensive feed	1	1	1	1	1	1	1	1	1
	Poor quality feed	2	2	2	2	2	2	2	2	2
	Limited fish seed supply	3	3	3	3	3	3	3	3	3
	Limited knowledge and skills	4	5	4	5	4	4	5	4	5
	Lack of niche market for aquaculture products	5	4	5	4	5	5	4	5	4
Hatchery operators	High fish mortalities in hatcheries	1	1	1	1	1	1	1	1	1
	Expensive hatchery feeds and related inputs	2	2	2	2	2	2	2	2	2
	Expensive and unreliable broodstock feeds	3	3	3	3	4	3	3	4	3
	High taxes imposed on hatchery inputs	4	4	4	4	3	5	4	3	4
	Water challenges in terms of quality and quantity	5	5	5	5	5	4	5	5	5
Fish traders	Limited capital	1	1	1	1	1	1	1	1	1
	Long distances to reach fish farms	3	2	2	2	2	2	2	3	2
	Inadequate supply of fish from farmers	2	3	3	3	3	3	3	2	3
	Fish market price fluctuations	4	5	5	4	4	4	4	4	5
	Poor transport infrastructure	5	4	4	5	5	5	5	5	4
Processors	Indequate capital	1	1	1	1	1	1	1	1	1
	Fish scarcity	2	2	2	2	2	2	2	2	2
	Lack of storage facilities	3	3	3	3	3	3	3	3	3
	Poor facilities for packaging and branding	4	4	4	4	4	4	4	5	5
	Test preference for wild fish to farmed fish	5	5	5	5	5	5	5	4	4
Transporters	Lack of specialised cooling systems	1	1	1	1	1	1	1	1	1
	Lack of enough fish to be transported	2	2	2	2	2	2	2	2	2
	Lack of sufficient ice supply	4	3	3	3	3	3	3	3	3
	High taxes	3	4	4	4	4	4	4	4	4
	Poor road network	5	5	5	5	5	5	5	5	5

Key: WAIP = West Nile Aquaculture Innovation Platform; WHAIP = Western Highland Aquaculture Innovation Platform; LACIP = Lake Albert Crescent Aquaculture Innovation Platform; NEAIP = North Eastern Aquaculture Innovation Platform; SEAIP = South Eastern Aquaculture Innovation Platform; NAIP = Northern Aquaculture Innovation Platform; SWHAIP = South Western Highland Aquaculture Innovation Platform; LVCAIP = Lake Victoria Crescent Aquaculture Innovation Platform; and SWRAIP = South Western Rangeland Aquaculture Innovation Platform. 1 = most pressing; 5 = least pressing.

In the WHAIP, NEAIP, SWHAIP and SWRAIP agro-ecological zones, where livestock farming is popular, farmers reported a lack of market for aquaculture products. However, the case was different in Mbarara, Nabuin, and the Tooro part of Rwebitaba, where cattle farming is dominant. This observation was surprising, particularly in the hilly Kigezi and the Rwenzori ranges, where fish acts as an alternative protein source due to the lack of pasture for livestock farming [27]. Since small-scale farmers aim to market fish within

their locality, these findings are not surprising in livestock farming zones, where fish is considered a taboo that negatively affects milk productivity, a practice that hinders aquaculture development [29]. To facilitate the marketability of farmed fish in such zones, the formation of producer groups (platforms) and the establishment of bulking centers for fresh or smoked and processed fish would enhance export to regional markets in neighboring Kenya or the Democratic Republic of Congo (DRC), where fish is highly regarded and where a ready market exists.

Although Kigezi is endowed with a vast number of minor water bodies (Mutanda, Mulehe, Kayumbu, and Bunyonyi), these water bodies do not support cage fish farming [30]. Therefore, the farmers in the region have relied on pond culture systems as their only option for fish production. During the IP formation process, fish farmers from this region (SWHAIP) highlighted constraints involved in fish farming. Such constraints included distant fingerling hatcheries that curtailed seed access, topography, and the dense population. The topography of the region consists of narrow, steep convex, and gentle slopes, while the landscape has steep slopes and deep, narrow valleys [31]. With such topography, the construction of fish ponds has become costly in the region. Additionally, with the fact that most hatchery operators are located in the central region (about 300 km from Kigezi), farmers in the SWHAIP region incur a lot of fingerling transportation costs. Relatedly, the distant travels stress the fingerlings and lower their survival rate during production. All of these factors discourage farmers in the region from engaging in aquaculture. In the same light, Kigezi is very densely populated [32], and densely populated areas experience high competition for land use (e.g., recreation, farming, and housing), which limits the availability of land suitable for aquaculture development [15].

3.4.2. Hatchery Operators

The hatchery segment of the aquaculture value chain is known to provide substantial employment opportunities [33]. Hatchery operators included actors that provide fish fry, fingerlings, juveniles, and post-juveniles to fish farmers. Although private hatcheries have emerged across zones to close the fish seed demand gap, it was reported that poor-quality fingerlings still persist. Workshop participants indicated high fish mortality in hatcheries as one of the major factors affecting their operations, a situation largely caused by aquatic animal health challenges. Relatedly, poor water quality was another factor identified by hatchery operators. Water quality is critical in hatchery operations because it affects the health and survival of fingerlings [26]. The health management of fish is thus a critical aspect of the hatchery business. According to studies by Walakira et al. [33], aquatic disease incidence contributes up to 60% of the mortality experienced in Uganda's fish hatcheries. Therefore, knowledge of minimizing disease outbreaks, disease monitoring, and management can make a difference between a profitable and a non-profitable farm. There is a need to build stakeholders' capacity to manage and acquire basic aquatic animal health management skills.

3.4.3. Fish Traders, Transporters, and Fish Processors

Deliberations with fish traders, transporters, and processors resulted in a number of issues of concern. For example, financial capital emerged as the top constraint across all zones for fish traders. A previous study in Kenya reported capital as a major bottleneck in fisheries [34]. Similarly, in Egypt, lack of access to credit was highlighted among the most important constraints to the development of aquaculture [35]. Challenges of access to financial capital were partly linked to limited access to loans. Often, a lack of ownership of critical assets such as land and equipment for use as collateral is a major barrier to access to credit in fisheries [34]. Similarly, findings from the present study indicated that traders complained about high interest rates from financial institutions. To solve this challenge, small groups of traders often come together to create informal financial groups through which they borrow funds amongst themselves at zero interest, as revealed during the focus group discussions.

The fish transporters highlighted that long distances from fish farms to markets, coupled with poor transport infrastructure, affect the timely delivery of live fish. For instance, traders from the Lake Victoria Crescent Aquaculture Innovation Platform reported experiencing high levels of fish mortality during transportation and distribution due to poor road networks in the central Uganda region.

Another key challenge identified from the focus group discussions was the volatility of fish prices. Both female and male traders reported challenges of ever-changing fish prices at fish farms. With the lack of timely and reliable market information, such as retail prices, fish traders assume great risk when purchasing fish and are often forced to sell at a loss.

Additionally, information collected during this study revealed that the transportation of farmed fish from producers to the local markets and consumers was mainly by road (motorcycles and small cars). Fish transporters also indicated a lack of specialized fish cooling and transport systems and financial limitations to procure items such as freezers and trucks fitted with chillers, which affected their activities. The high cost of maintaining cold rooms is a significant challenge for fish transporters and processors [36]. Studies have, however, observed that through cooperate marketing, farmers can acquire post-harvest handling facilities, which also stabilizes market prices [37,38]. Investments in cold chain and post-harvest handling facilities for small-scale pond farmers, in a cooperative form, allows for fish storage until traders reach the farm, thereby improving their bargaining power in the market [36]. Fish transporters suggested that improvements to roads to facilitate quicker transportation to markets will reduce post-harvest losses, as suggested by Awuor et al. [39].

Like the traders, processors ranked limited capital as their top constraint. Although most processors participated in local rotating credit and savings groups, they were faced with conditional bottlenecks such as lack of collateral and high interest in accessing credit from financial institutions. Although micro and small enterprises constitute over 96% of the business organizations in Uganda [40], they fall short of addressing the above financial needs in the aquaculture sub-sector. It is assumed that financial instruments designed for the agricultural small-holder farmers would as well work for the aquaculture sector, but this has not succeeded.

Another key constraint identified through focus group discussions was the unsustainable fish supply. Processors highlighted that as a result of fish scarcity, they often return home without fish, despite already having incurred transportation expenses to the fish farms. However, it was observed that fish processors in the aquaculture value chain across the nine zones were very few. The main reason for the limited number of fish processors seems to be associated with consumer preferences of fresh farmed fish to processed fish, as previously reported in Kenya [36]. To ensure business interactions between different value chain actors, digital platforms need to be implemented. It has been reported that digital platforms provide businesses with new opportunities to reach markets and consumers more efficiently [41].

3.4.4. Financial Institutions

Aquaculture still faces limited financing options despite the existence of government initiatives [34]. In this light, the uptake of credit from formal financial institutions to support aquaculture value chains is limited. During this study, different financial institutions noted that most farmers do not keep records that would enable them to qualify for funding or loans (Table 4). It was also observed that small-scale farmers across the zones generally exhibited low levels of professionalism; their fish farms were often unregistered, had no record keeping systems, and had no business plans. These factors rendered them financially excluded from loan considerations from most financial institutions in the country. This indicates that most small-scale fish farmers use their personal finances or other sources of income to finance aquaculture activities. Previous studies in Uganda and Tanzania noted that personal finance was the main source of income for small-scale farmers, followed by loans [27,42], and this aligns with the current findings. To ensure efficiency, it is essential to

offer technical assistance, including entrepreneurship and financial skills, to farmers and to continuously advocate for a specialized financial package for aquaculture enterprises. This would improve farming practices and build capacity to pay aquaculture loans.

3.4.5. Extension Workers

Aquaculture extension has played an important role in the development of the aquaculture industry in Uganda [43]. Extension service provision involves interventions and activities that facilitate access to and proliferation of knowledge, information, and technologies among farmers [43]. In the present study, it was observed that farmers who live within close proximity of extension workers' offices utilized the opportunity to request farm visits. The extension workers confirmed that such farmers received more visits because of the low transportation costs. Extension workers highlighted low staffing levels, underfunding, and poor linkages between research and extension as major challenges facing Uganda's aquaculture extension services (Table 4). A related observation was reported by Atukunda et al. [43], who indicated that a lack of transport and low staff capacity affected on-farm advisory services in the districts of the central and northern regions of Uganda.

During the course of this study, extension workers reported an unsustainable government policy of supplying free fish feeds and fish fries to farmers. According to the extension workers, this kind of arrangement raises farmers' expectations for free services, creates a dependency syndrome, and does not empower farmers to run their fish farming enterprises with a commercial attitude. Consequently, farmers make unrealistic demands that are beyond the means of the extension workers.

Possible solutions such as advocating for increased funding, the mobilization of farmers in groups, mindset change, generating market information, capacity building (refresher courses), the recruitment of more extension workers, and proper coordination of aquaculture issues at all levels were suggested. Exploring the most desired solution, extension workers agreed that linkages between extension and research need to be enhanced for effective service delivery to fish farmers. They further observed that several interventions had been advanced with the aim of introducing multi-disciplinary, holistic, and participatory approaches; however, aquaculture extension aspects were still handled using a top-down approach and with poorly trained extension staff. Extension workers thus suggested that effective technical training and skills improvement courses should be developed to upgrade the competencies of extension technical staff. Additionally, extension workers regarded farmer groups as a feasible means to facilitate the dissemination of aquaculture information and technologies to fish farmers, particularly where government funds were insufficient to conduct routine farm visits.

3.4.6. Input Dealers or Suppliers

Sustainable input supply is a key aspect of aquaculture development [44]. Aquaculture input suppliers sell inputs to sustain fish farming. These include: fish seed, feed ingredients, broodstock, fish feed, fish medicines, and harvesting gear. These suppliers play an essential role in the aquaculture value chain, and their activities, to an extent, determine the level at which fish farmers operate and, hence, the quality and quantity of aquaculture production. Investigations undertaken during this study revealed that the main challenges experienced by input suppliers include the high costs of feed ingredients and competition for feed ingredients between humans and animals. Input dealers also revealed the high adulteration of feed ingredients, e.g., silverfish "mukene", which is commonly mixed with sand to increase weight. A similar challenge was encountered with maize bran and sunflower seed cake, which are major ingredients used by farmers for on-farm feed formulations. Similar observations of ingredient adulterations have also been reported by Sarkar et al. [45], yet no regulations have been advanced to curb this vice [46]. In addition, suppliers reported challenges of inconsistent raw material supply, caused by the fact that most feed ingredient producers, such as soybean farmers, could not guarantee a stable and consistent supply throughout the year. This leads to price fluctuations, espe-

cially during the off-season period, which further complicates production. The inadequate training of input dealers by government agencies necessitates a substantial investment in human capital and infrastructure in zonal research institutes. This will enable input dealers to access fundamental services like feed formulation and analysis. Furthermore, it is important that regulatory agencies rigorously monitor the quality.

Table 4. List of key constraints as identified by financial institutions, extension officers, input dealers, and researchers during zonal aquaculture innovation IP workshops in the various agro-ecological zones around Uganda.

Category	Constraints Identified	Ranking of Challenges According to Innovation Platforms								
		WAIP	WHAIP	LACIP	NEAIP	SEAIP	NAIP	SWHAIP	LVCAIP	SWRAIP
Financial institutions	Poor record keeping by farmers	1	1	1	1	1	1	1	1	1
	Uncertainty related to climate change	2	2	2	2	2	2	2	2	2
	Lack of proof of experience in fish farming by farmers	3	3	3	3	3	3	3	3	3
	Perishability risk of fish is high	4	4	4	4	4	4	4	4	4
	Failure of farmers to run their fish farms as a business	5	5	5	5	5	5	5	5	5
Extension officers	Under-funding of the aquaculture sub-sector	1	1	1	1	1	1	1	1	1
	Low staffing levels	2	2	2	2	2	2	2	2	2
	Inadequate logistics	3	3	3	3	3	3	3	3	3
	Unsustainable government policies	4	4	4	4	4	4	4	4	4
	Poor linkages between research and extension	5	5	5	5	5	5	5	5	5
Input dealers	Poor-quality feed ingredients	1	1	1	1	1	1	1	1	1
	Prices of the imported feed is extremely high	2	2	2	2	2	2	2	2	2
	Limited access to financial services (credit/insurance)	3	3	3	3	3	3	3	3	3
	Competition between humans and animals for feed ingredients	5	5	5	4	4	4	4	4	4
	Adulteration of feed by manufacturers or traders	4	4	4	5	5	5	5	5	5
Researchers	Disconnect between researchers and extension workers	2	2	2	1	1	1	1	1	1
	Limited funding for research	1	1	1	2	2	2	2	2	2
	Scattered responsibilities from different agencies	4	3	3	3	3	3	4	4	4
	Long application process of ethical approval	3	4	4	4	4	4	3	5	5
	Low staffing levels	5	5	5	5	5	5	5	4	4

Key: WAIP = West Nile Aquaculture Innovation Platform; WHAIP = Western Highland Aquaculture Innovation Platform; LACIP = Lake Albert Crescent Aquaculture Innovation Platform; NEAIP = North Eastern Aquaculture Innovation Platform; SEAIP = South Eastern Aquaculture Innovation Platform; NAIP = Northern Aquaculture Innovation Platform; SWHAIP = South Western Highland Aquaculture Innovation Platform; LVCAIP = Lake Victoria Crescent Aquaculture Innovation Platform; and SWRAIP = South Western Rangeland Aquaculture Innovation Platform. 1 = most pressing; 5 = least pressing.

3.4.7. Researchers

The focus group discussions with researchers across the nine zones revealed that aquaculture production systems in Uganda are grouped into three categories, which include extensive, semi-intensive, and intensive systems. This grouping is based on the level of production, capital investment, labor, and management practices employed. The researchers engaged in this study comprised actors from agricultural research institutes, agricultural education and training institutes, and universities working with the aquaculture value chain.

During this study, it was noted that inadequate government funding for aquaculture research has hindered the ability to effectively address crucial challenges within the aquaculture sub-sector (Table 4). It was, however, demonstrated that researchers have contributed towards generating research technologies, new products, and better ways of increasing aquaculture productivity. For instance, as a way of improving the quality of fish seed in Uganda, some interventions on Nile tilapia strain improvement have been initiated to improve the quality of fish feed; new fish feed formulae have been developed using locally available least-cost ingredients. Additionally, researchers have introduced innovative value-added technologies, such as the fish smoking kilns that reduce cancer compounds.

During the focus group discussions, researchers proposed new suggestions, which included the adoption of advanced scientific fish breeding methods such as selective breeding and mono-sex breeding of local species.

Researchers further underpinned the need for advancing more climate-smart and gender-sensitive technologies. Researchers indicated the need to design and test appropriate aquaculture labor-saving technologies for women, men, and youth, with a focus on testing and promoting integrated aquaculture systems and water management practices for enhanced productivity for smallholder farmers.

3.5. Existing Opportunities within the Aquaculture Sub-Sector

The aquaculture sub-sector has tremendous potential to contribute to income, youth employment, food security, and livelihoods in Uganda. Currently, aquaculture production has been improved by the introduction of cage farming on Lake Victoria and the involvement of major commercial fish farmers. This has played a crucial role in driving the growth of the industry in the country. Highly productive cage systems have been perceived as an important driver of sustainable aquaculture growth in Africa [44]. While this initiative is a step in the right direction, the Ugandan government has a crucial role to play in regulating the expansion of cage aquaculture so that biosecurity and environmental standards are not compromised. In the same regard, Uganda has great potential for developing aquaculture beyond small-volume production models into larger commercial-scale production operations using both cages and land-based systems.

This country has diverse agro-ecological zones, offering a favorable potential for the promotion of fish farming. This country also has suitable climatic conditions and enormous water resources for fish production that provide the potential to fill the current and future supply gap in domestic, regional, and international markets by promoting efficient, commercial, profitable, and sustainable aquaculture production.

Through the emergence of commercial agriculture as a means to increase the livelihoods of actors along the value chain, the government, through the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF), adopted the Commodity-Based Approach (CBA) to increase agricultural production and productivity. In this framework, fish is one of the priority commodities that the MAAIF is pursuing under the Agriculture Sector Strategic Plan, and the promotion of commercial aquaculture has been identified as a priority intervention.

Additionally, the extensive freshwater resources in Uganda support fast-growing fish species such as Nile tilapia and African catfish that are suitable for cage, pond, and tank-based aquaculture systems. Other high value species such as Nile perch (*Lates niloticus*), Bagrid catfish (*Bagrus docmac*), Ningu (*Labeo victorianus*), Ripon barbel (*Barbus altianalis*),

Synodontis spp., Elephant snout fish (*Mormyrus kannume*), and African lungfish (*Protopterus aethiopicus*) have not been substantially exploited.

Under the regulatory provisions, the Fisheries and Aquaculture Act 2022 provides a framework for the formulation of policies and the transparent and accountable management of the fisheries and aquaculture sectors. This act takes into account fish quality control issues, the diversification of fish products for domestic and international markets, the regulation of imports and exports, and strengthening the infrastructure for domestic, regional, and international trade.

4. Conclusions

The objectives highlighted by the nine innovation platforms confirm their potential for addressing a range of short-term production risks and long-term goals of sustainable aquaculture production. This study demonstrates that actors within an IP face multiple challenges (including developmental, material, and economical challenges). As highlighted, there are technical knowledge gaps across the entire aquaculture value chain, mainly affecting hatchery operators, input suppliers, and farmers. Farmers rely heavily on technical assistance from local government fishery officers and extension workers. There is a need to increase the technical capacity of the entire value chain, from feed producers, hatchery operators, and traders to farmers to improve their production efficiency, profitability, and sustainability. Despite the availability of local ingredients, input dealers reported challenges such as adulteration and high prices for feed ingredients, particularly protein-based sources, due to competition from other users and seasonal availability. Key activities underlined by different actors, to be implemented across aquaculture innovation platforms for the next project period, are summarized as follows:

- Improving the technical capacity of the entire value chain, from feed producers, hatchery operators, traders, and farmers. This will significantly improve their production efficiency, profitability, and sustainability.

- Conducting research on black soldier fly farming as a potential alternative animal protein source to fishmeal.

- The formation of social network groups to enhance communication among various value chain actors.

- Putting up mechanisms for the IPs to communicate with each other for resource mobilization and information sharing.

- Supporting local seed production, possibly through promoting a partnership between feed manufacturers and existing hatcheries.

- Encouraging extension workers to constantly visit farmers to enhance their knowledge and skills.

- Improving the technical capacity of fish traders and farmers in entrepreneurship and financial literacy. This would improve their farming practices and build their capacity to access loans from financial institutions.

- Linking farmers to markets and marketing groups for better fish pricing.

- Lobbying for more funding towards fish farming for the farmers to increase fish production.

5. Limitations of This Study

Several lessons can be drawn from our study to understand the institutional constraints and opportunities for change. By establishing IPs and supporting their activities, the AIRTEA project seeks to catalyze change. However, a major challenge identified was the limited participation of women during the establishment of IPs. Furthermore, during stakeholder engagement, some participants did not feel comfortable expressing their opinions in a formal group context. In some regions, many divergent views were raised by different value chain actors, which delayed the process of reaching a consensus. It was also observed that financial institutions in some regions were not well represented, potentially influencing the outcome of discussions. While multi-stakeholder workshops

facilitated the sharing and discussion of ideas among different stakeholder groups, unequal power dynamics and differences in the ability to debate and negotiate may have had an impact. Despite these limitations, the nine workshops provided a ‘fast-track’ approach to identifying entry points for innovation.

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